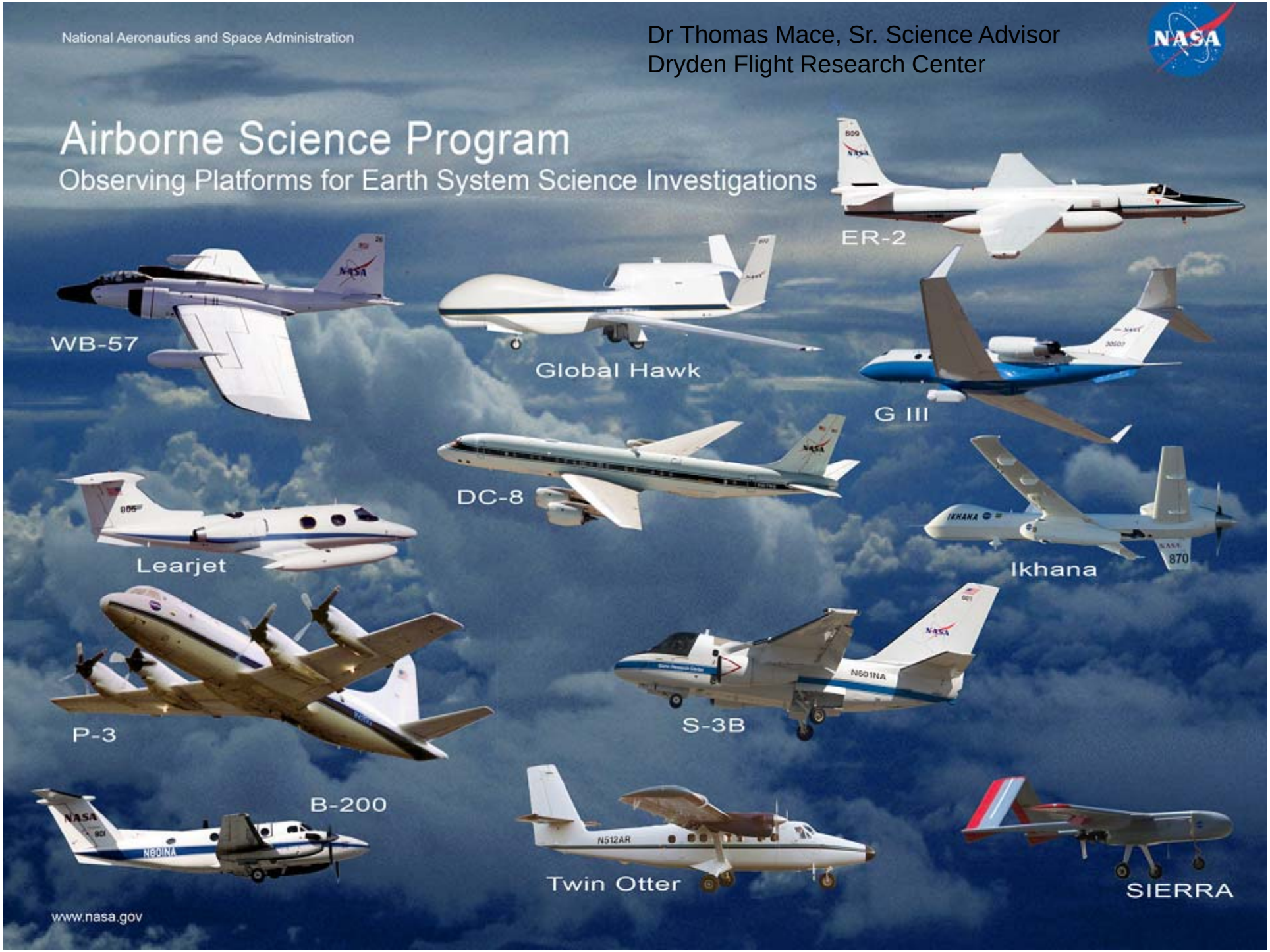
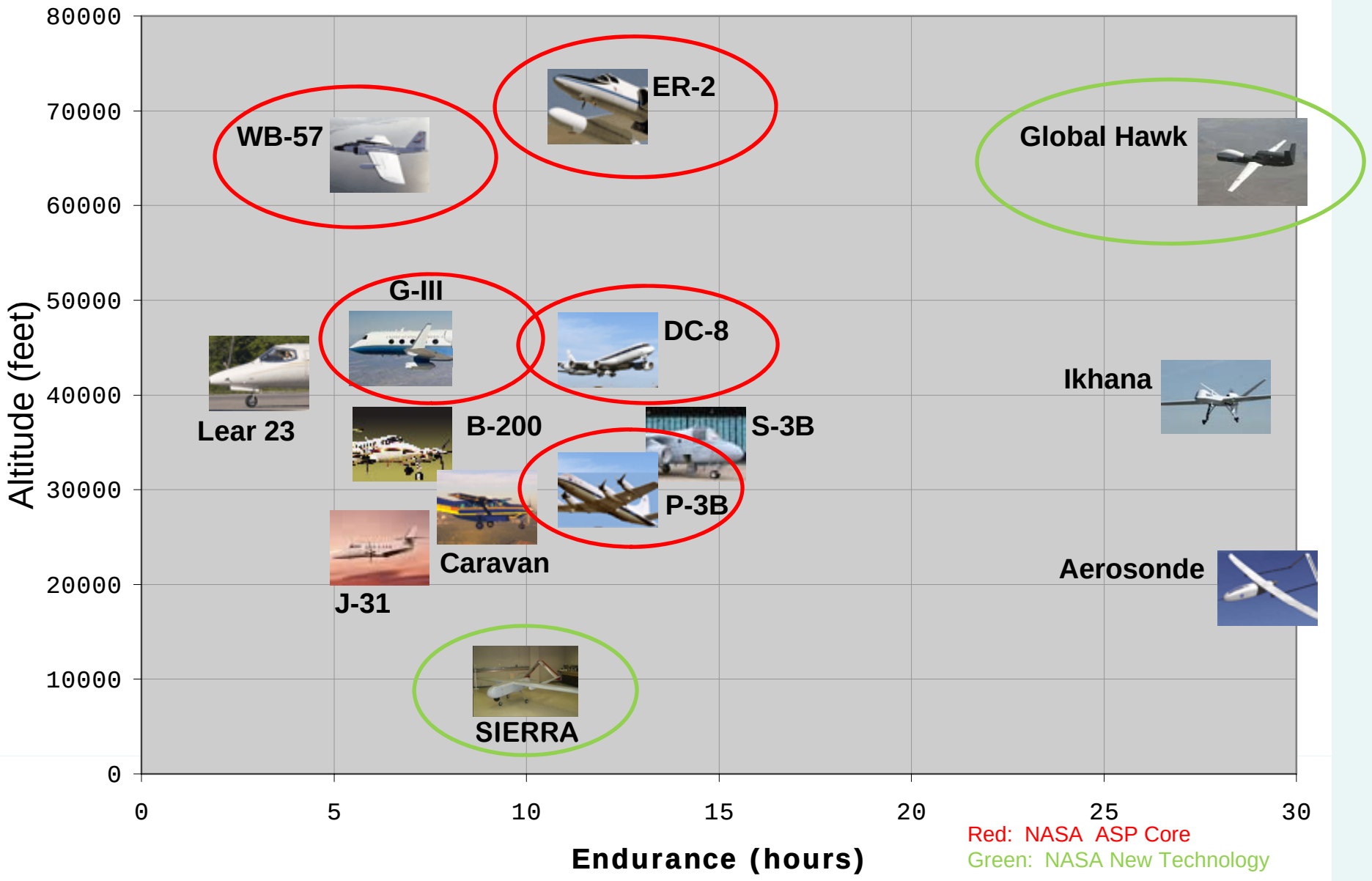
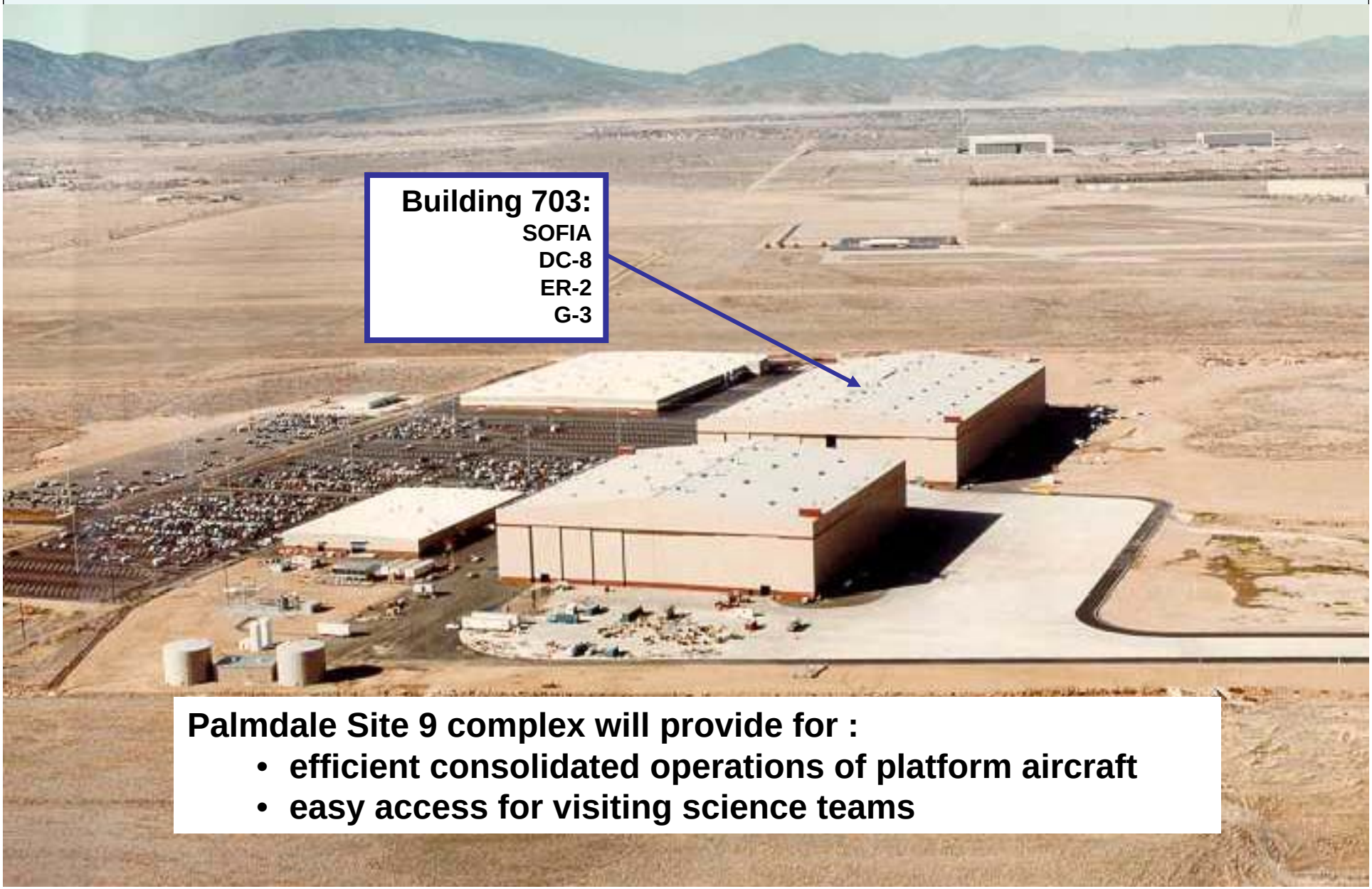

National Aeronautics and Space Administration
Dr Thomas Mace, Sr. Science Advisor
Dryden Flight Research Center
Airborne Science Program
Observing Platforms for Earth System Science Investigations
ER-2
WB-57
Global Hawk
G III
DC-8
Learjet
Ikhana
P-3
S-3B
B-200
Twin Otter
SIERRA
www.nasa.gov

NASA Unique Airborne Science Aircraft



Dryden Aircraft Operations Facility

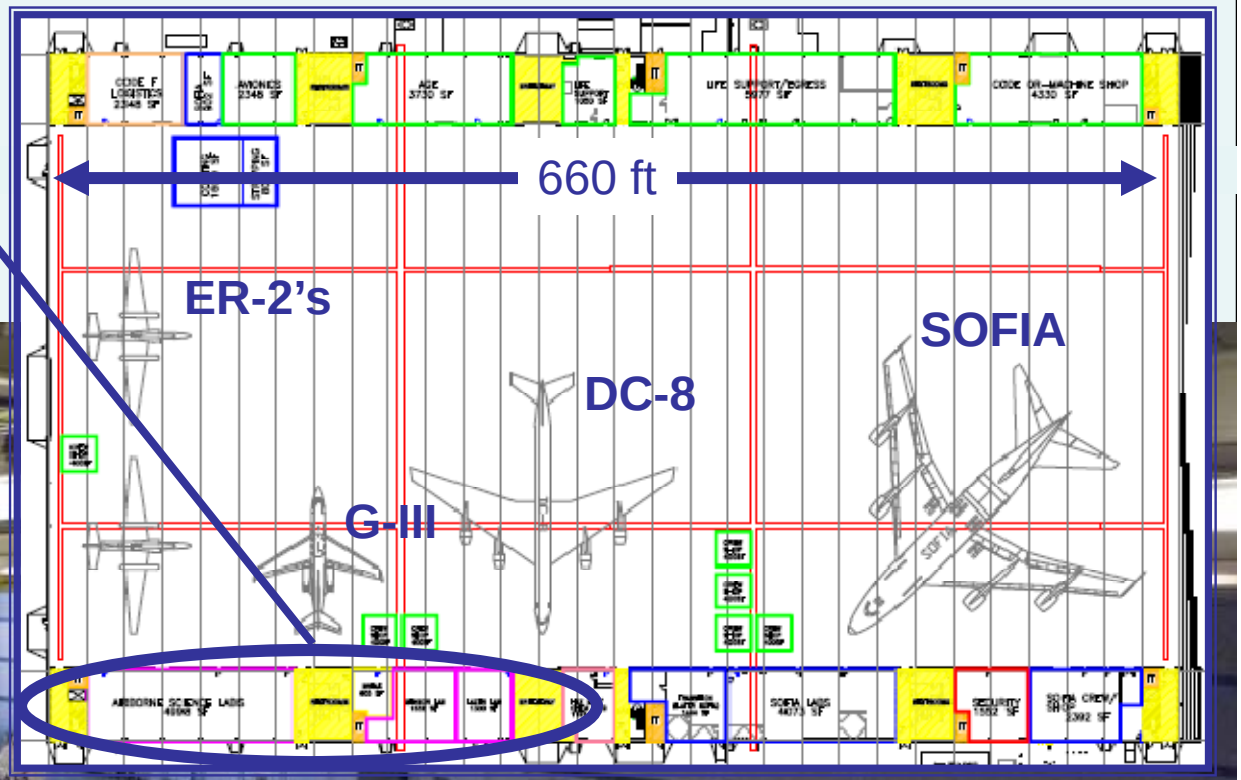


Palmdale Site 9 complex will provide for :

- **efficient consolidated operations of platform aircraft**
- **easy access for visiting science teams**

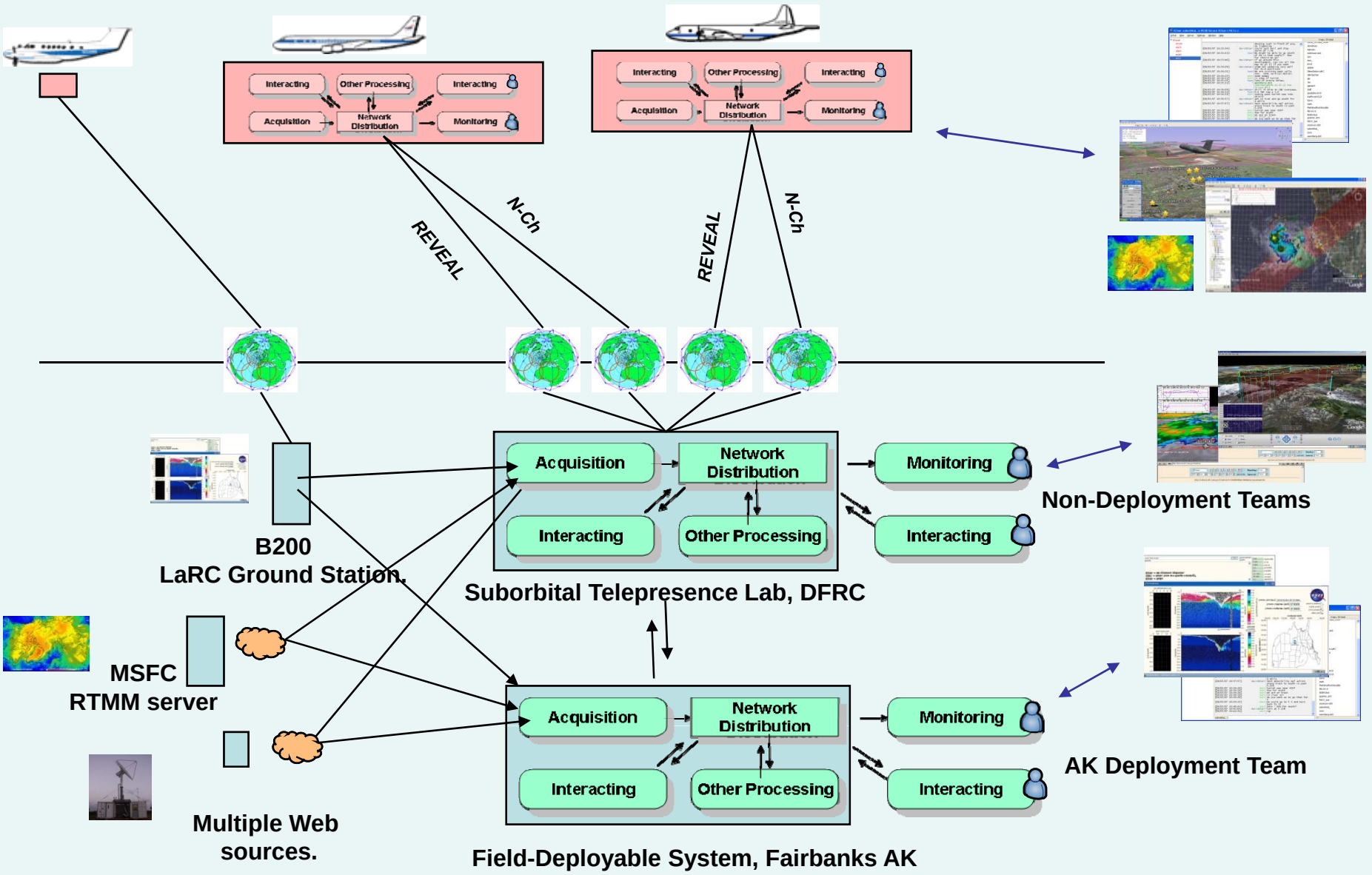
DAOF

Science Integration Labs



– New Technology –

Sub-Orbital Tele-Communications



DC-8 Flying Laboratory

Large Capacity, Long Range and Endurance

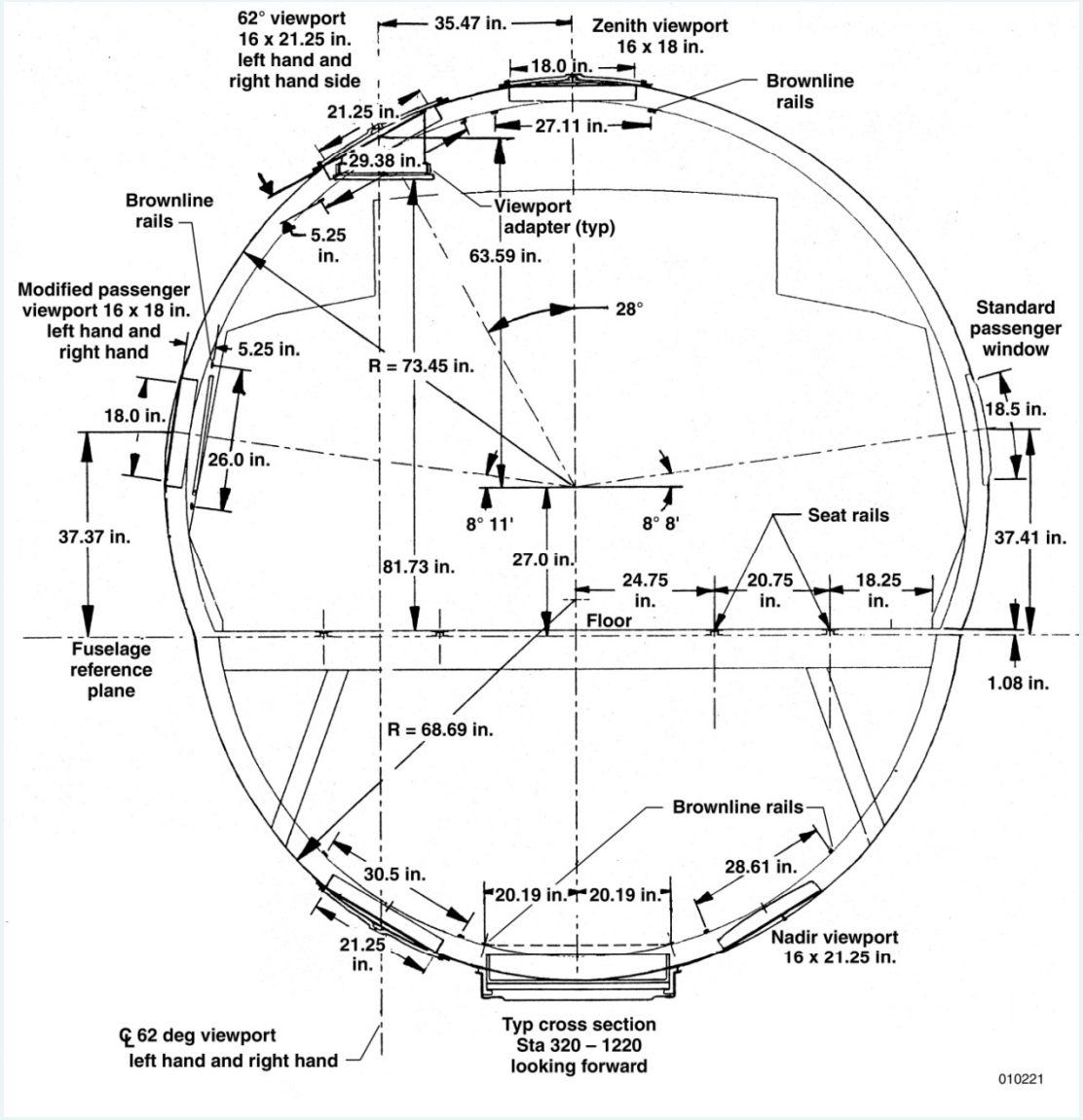
Capabilities

- Ceiling 42,000 ft.
- Duration 12 hours
- Range > 5,400 nautical miles
- Payload 30,000 lbs

Mission Support Features

- Shirtsleeve environment for up to 30 researchers
- Worldwide deployment experience
- Extensive modifications to support in-situ and remote sensing instruments
  - zenith and nadir viewports
  - wing pylons
  - modified power systems
  - 19 inch rack mounting

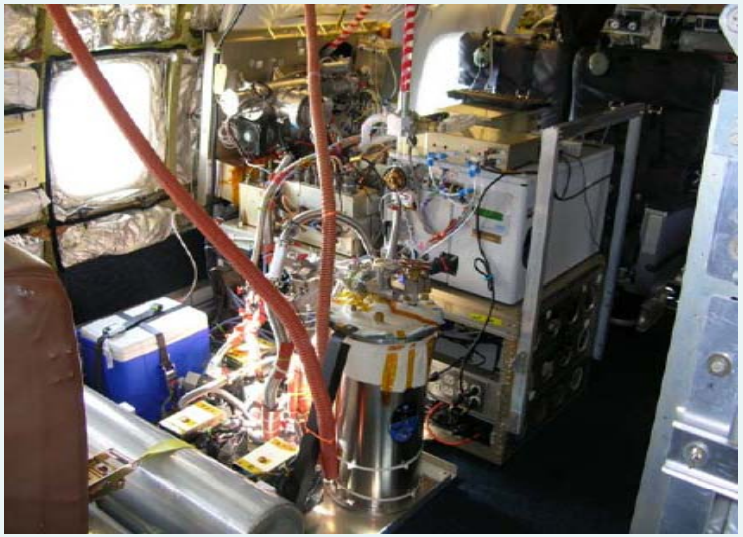
DC-8 Viewports



– Recent Campaigns –

ARCTAS

Examples of External Instrumentation



ER-2

Very High Altitude, Long Range and Endurance

Capabilities

- Ceiling > 70,000 ft
- Duration > 10 hours
- Range > 4,000 nautical miles
- Payload 2,600 lbs
  (700 lbs in each wing pod)

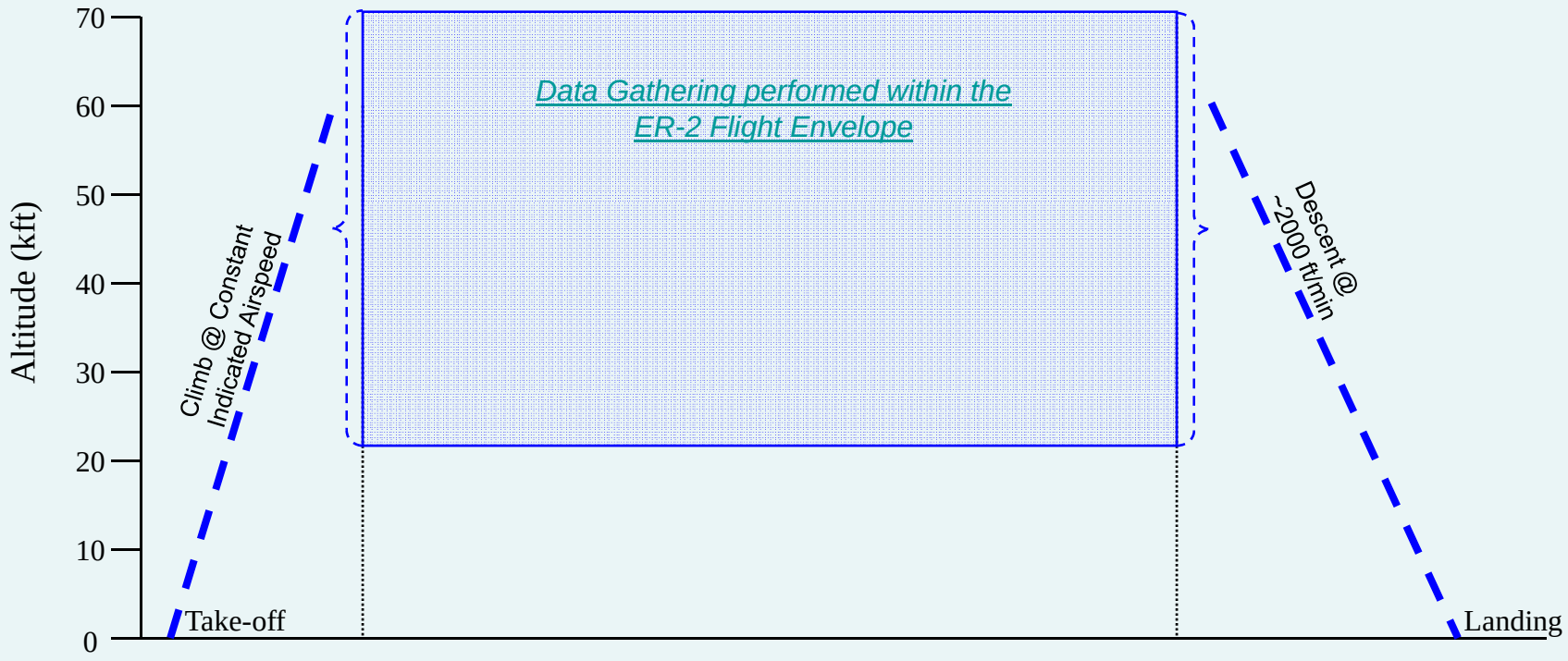
Mission Support Features

- Multiple locations for payload instruments
- Pressurized and un-pressurized compartments
- Standardized cockpit control panel for activation and control of payload instruments
- World-wide deployment experience

Background and Status

- U-2 and ER-2 aircraft have been a mainstay of NASA airborne sciences since 1971
- Over 100 science instruments integrated
- Two aircraft

ER-2
Typical Data gathering Profile



ER-2 Instrument Integration Locations

– Recent Campaigns –

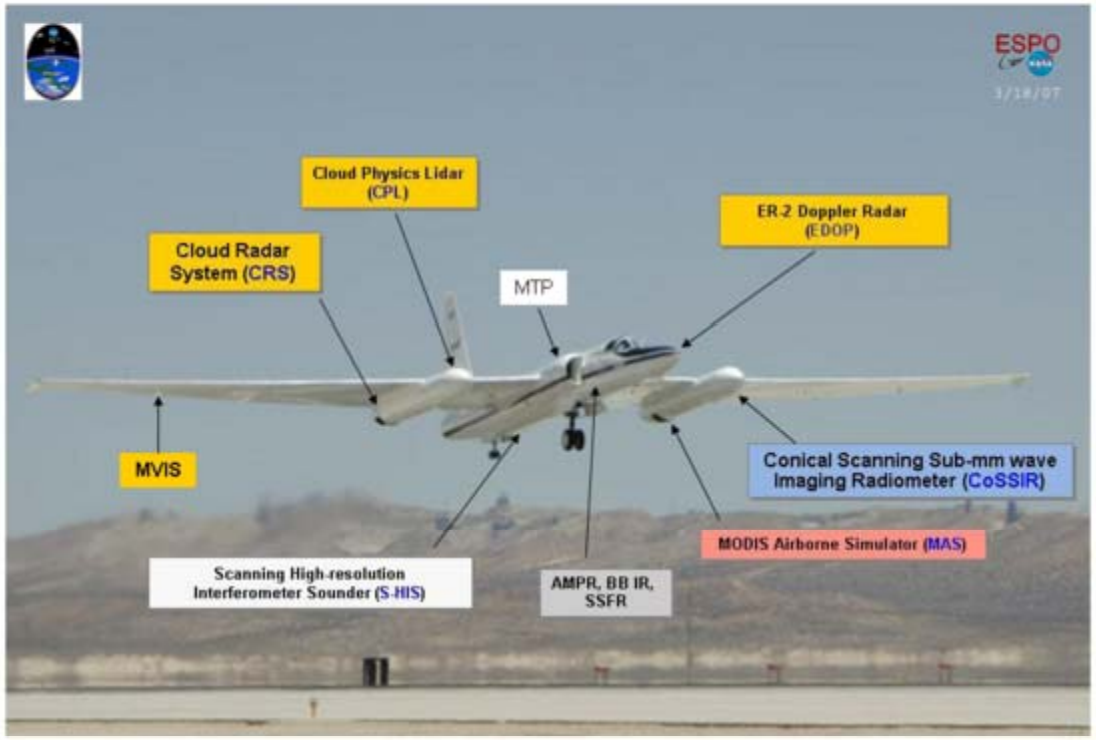
TC-4

Tropical Composition, Climate and Cloud Coupling

Goal: Investigate the structure, properties and processes in the tropopause transitional layer of the tropical Western Pacific.

Validate Aura and CALIPSO/CloudSat satellite data.

Participating Aircraft: ER-2, DC-8 and WB-57

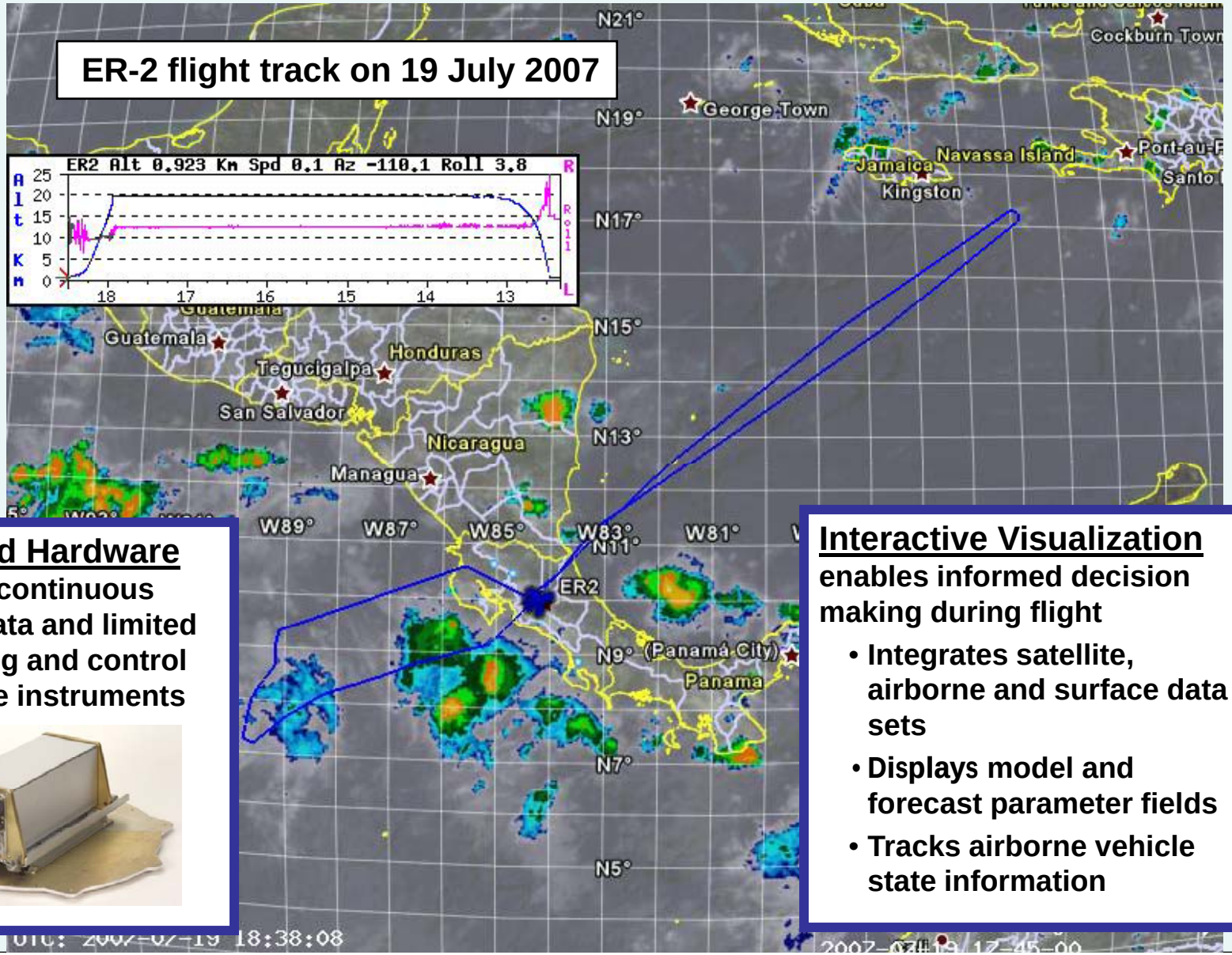


TC-4 Science/Aircraft Team On-Station in Costa Rica

NASA ER-2 deployed to San Jose, Costa Rica with 9 remote sensing instruments, August 2007

– Recent Campaigns –

TC-4 Real-Time Mission Management



<u>On-board Hardware</u>
provides continuous aircraft data and limited monitoring and control of science instruments

<u>Interactive Visualization</u>
enables informed decision making during flight

- **Integrates satellite, airborne and surface data sets**
- **Displays model and forecast parameter fields**
- **Tracks airborne vehicle state information**

- Global Hawk Overview -

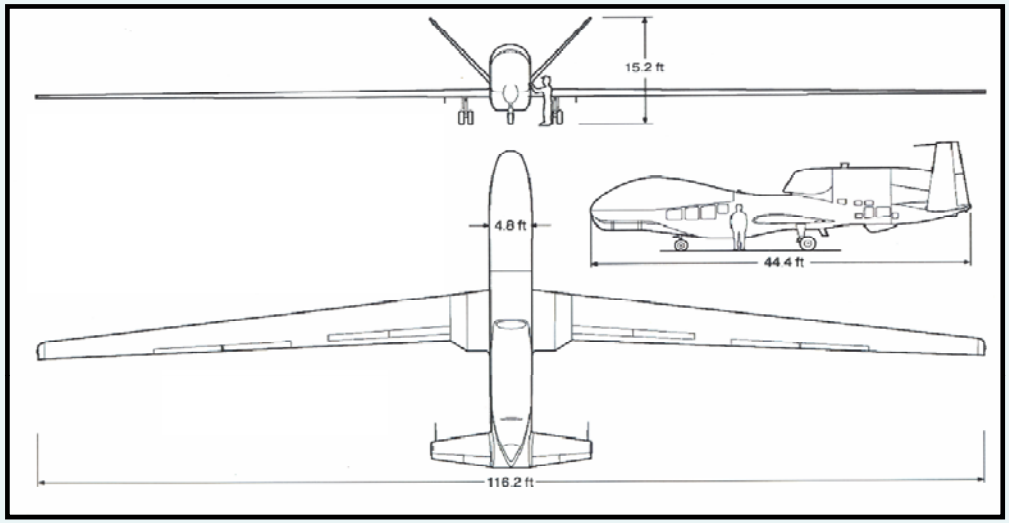
NASA Global Hawks

- Two Advanced Concept Technology Demonstration (ACTD) aircraft transferred to NASA in September, 2007 (AV-1 and AV-6).
- Aircraft are based at the Dryden Flight Research Center on Edwards Air Force Base.
- Configuration and performance similar to standard ‘Block 10’.

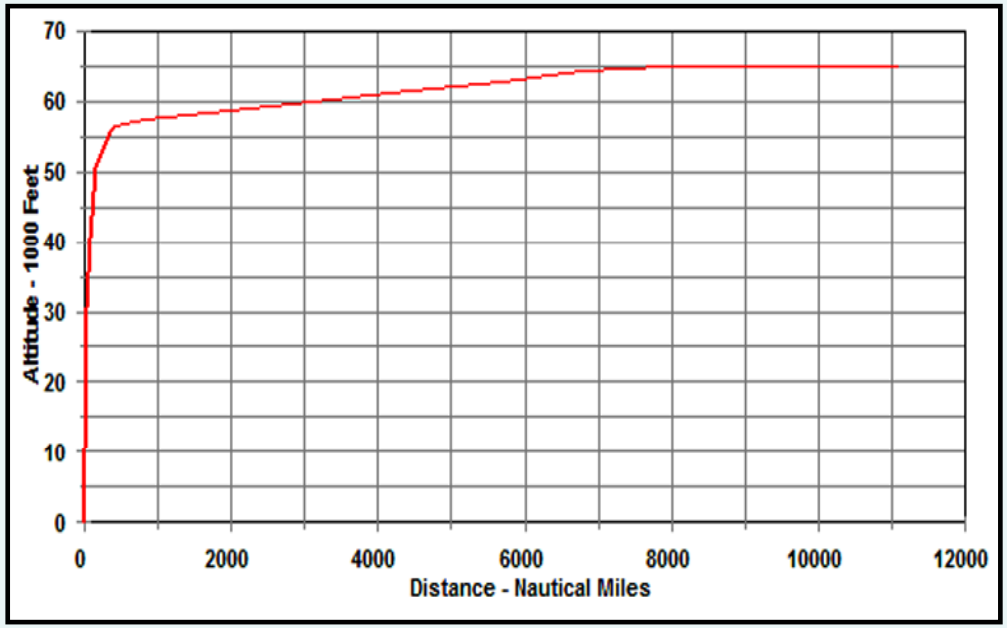
Global Hawk Overview

Northrop Grumman RQ-4

- **Long range, unmanned, autonomous, reconnaissance vehicle.**
- **Operational vehicles are in service with US Air Force (Block 10 and 20) and Navy (Block 10).**
- **Other variants under development.**



Block 10 Specifications	
Endurance	> 30 hours
Service Ceiling	> 60,000 ft
Range	> 11,000 nmi
Payload	~ 1,500 lb
Length	44 ft
Wingspan	116 ft

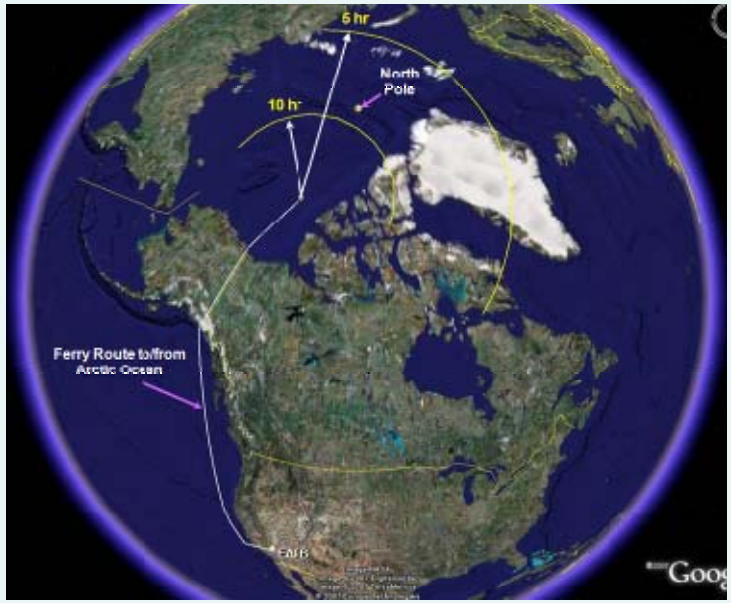


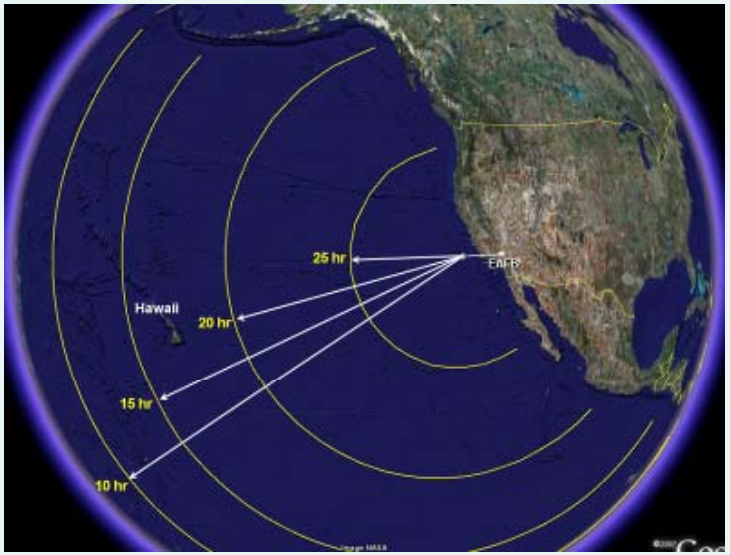
- Global Hawk Overview -

NASA - Initial Science Operations

Flight Operations

- **Based at NASA Dryden, Edwards Air Force Base.**
  - **Long-duration data collection over the Arctic, Pacific and Western Atlantic oceans.**
  - **Flight over land will follow the same corridors already in use by GH, when practical.**

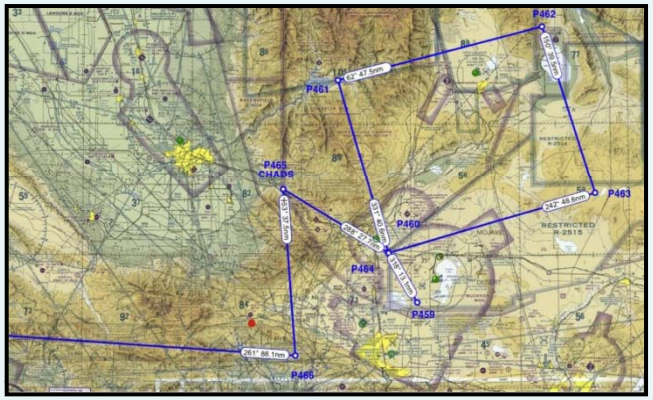




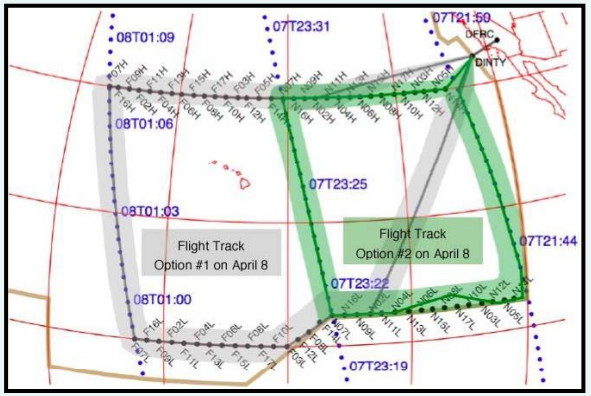
- Global Hawk Overview -

NASA - Initial Science Operations

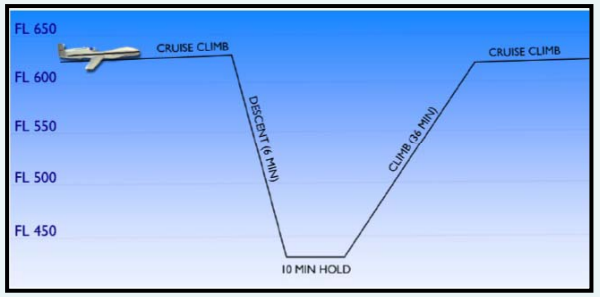
Flight Operations, cont.



- **Aircraft flies below FL 420 only in the EAFB restricted range.**



- **Flight routing**
  - **A nominal flight path (multiple way-points) is programmed prior to flight.**
  - **Alterations from the nominal path are executed with additional way-points during flight.**



- **Vertical profiling for science objectives**
  - **Must remain above conventional air traffic.**
  - **Depends on knowledge of the hazard environment (icing, convective systems, etc).**
  - **Has small impact on range/duration capability.**

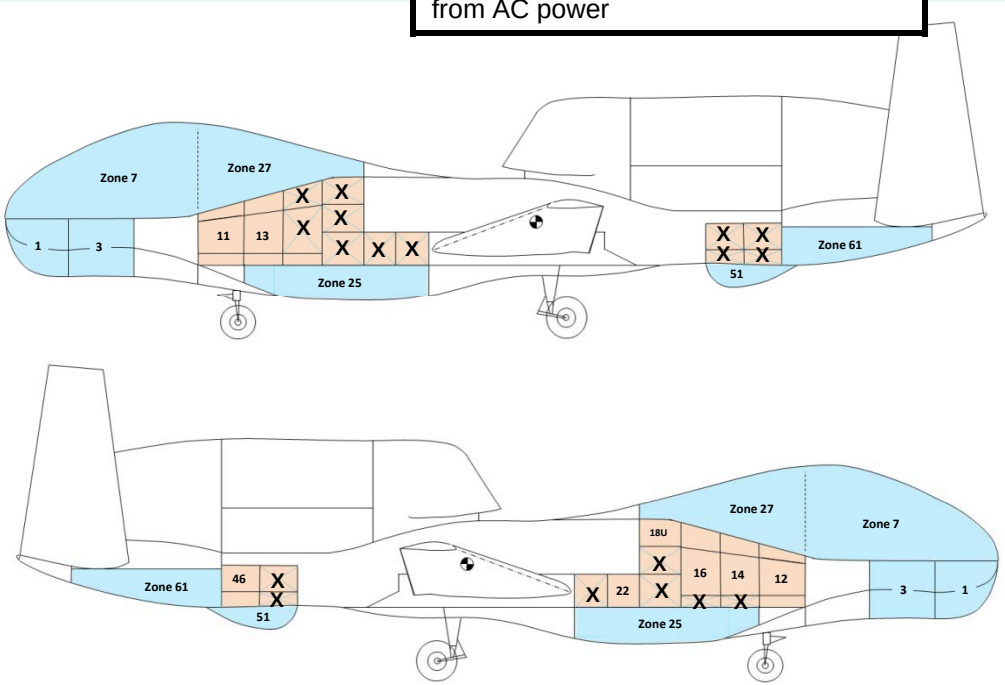
- Global Hawk Overview -

NASA - Initial Science Operations

Instrument Accommodations

Power for Experiments	
DC	2.0 KW
AC	8.2 KVA
Additional 7.8 KW DC can be derived from AC power	

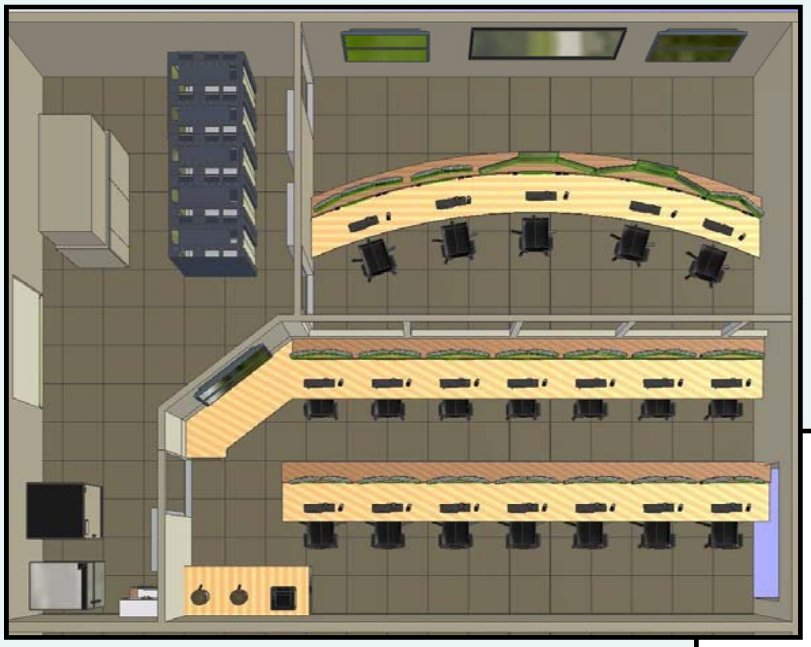
- **Total payload weight ~ 680 kg (1,500 lbs)**
- **Multiple compartments**
  - **Standardized power and command/control interface (EIP's)**
  - **Some ECS controlled**
    - **Pressure alt < 8.2 km**
    - **0 < Temp < 55° C**
    - **No condensation**
  - **Some w/19" rack mounting**
- **Integration**
  - **Conducted by NASA / Northrop Grumman team**
  - **Pre-flight simulations**
    - **Full mission duration**
    - **Extreme environments**
    - **Full functional check-out**



- Global Hawk Overview -

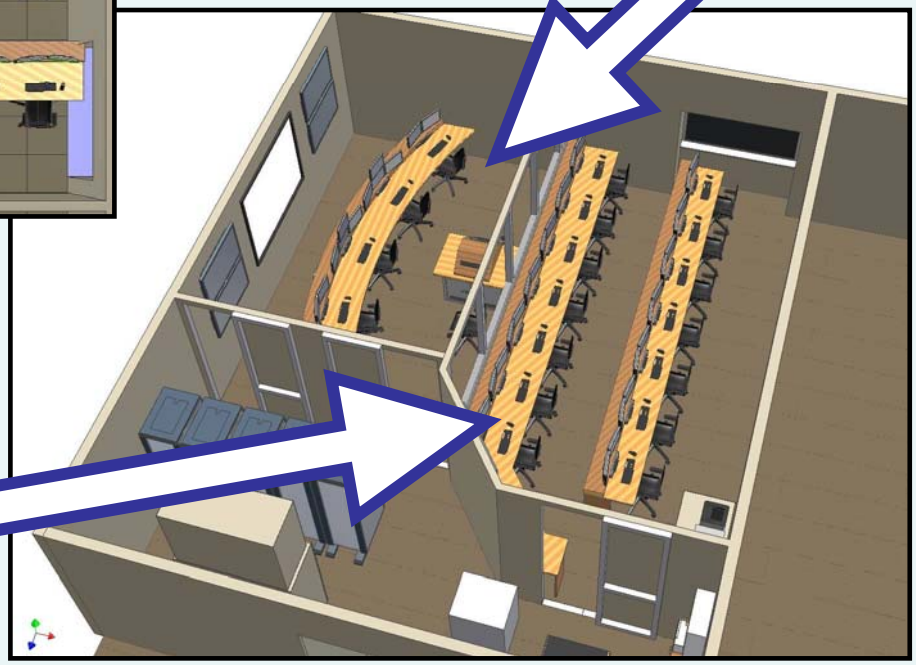
NASA - Initial Science Operations

Global Hawk Operations Center (GHOC)



Flight Operations

- Pilot, science mission specialist + others
- Vehicle control, navigation, air traffic coordination
- Control of science payload power and inhibits

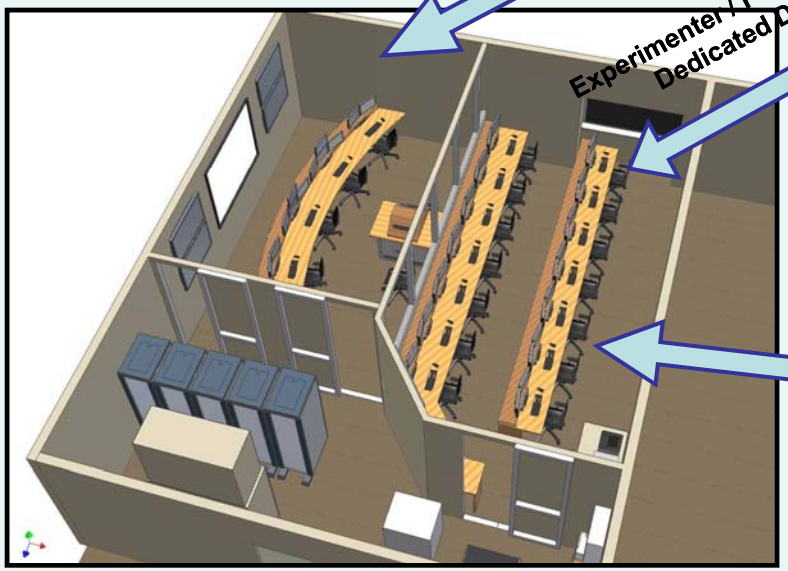


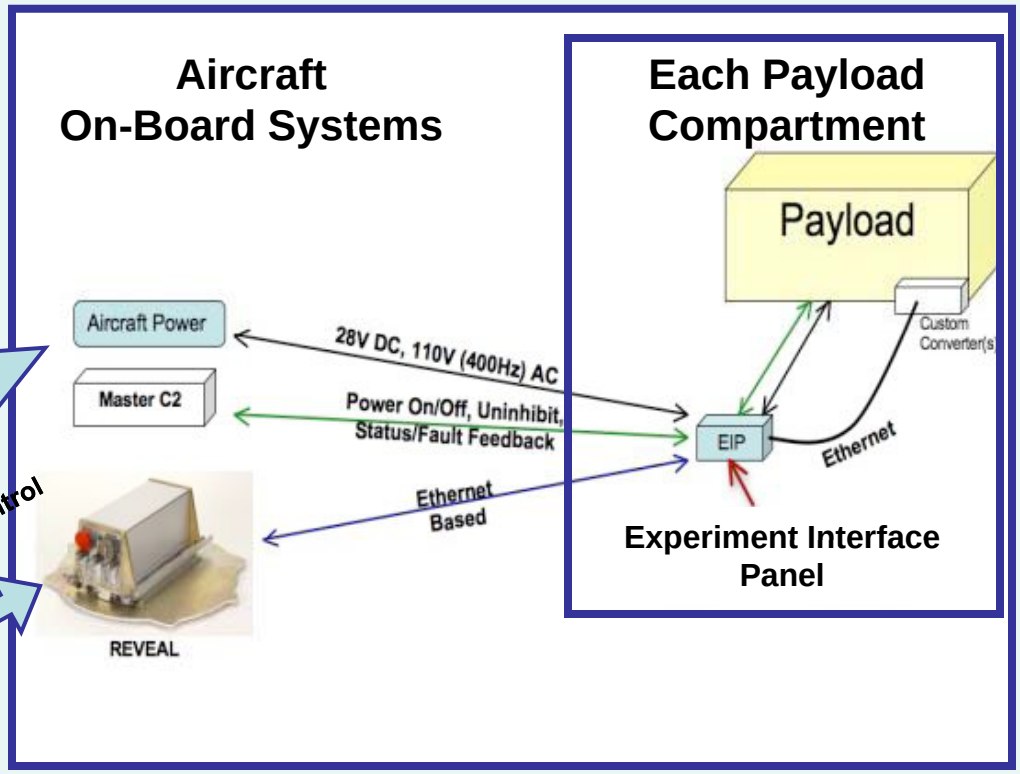
Payload Operations

- Experiment team collaboration
- Data monitoring and control of science instruments
- Access to external science community through internet

- Global Hawk Overview -

NASA - Initial Science Operations





Internet

Distributed Science Team (worldwide)

- Global Hawk Overview -

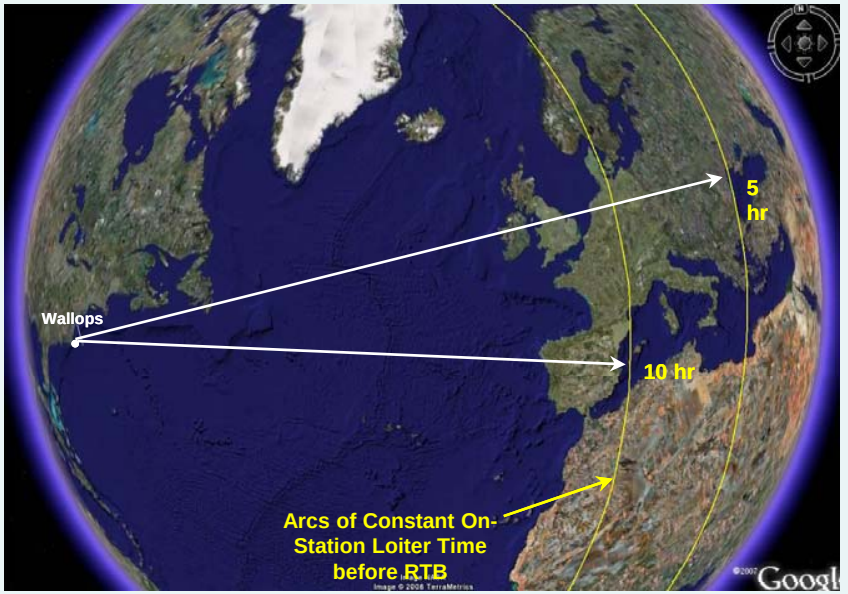
NASA – Future Capabilities

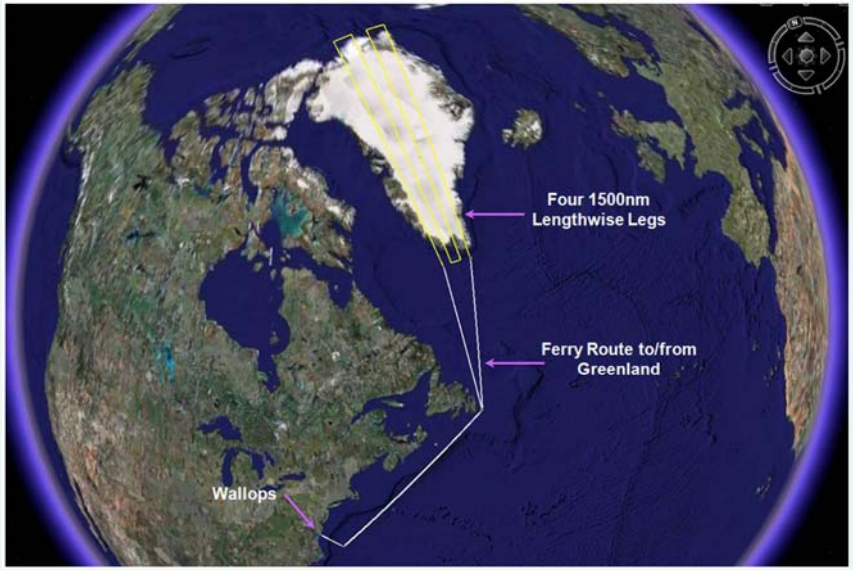
Deployment to U.S. east coast

- Extended operations over eastern Atlantic.
- Extended operations over Greenland.

Key requirements

- Portable ground control station development (take-off and landing only).
- Extensive logistics (potentially site improvements) to support ground infrastructure.
- Frequency and airspace coordination at remote facility.





NASA – Future Capability

Removable payload enclosures.

- Would allow science teams to integrate their equipment in parallel with other aircraft activities and at their own facilities.
- Requires design and development.

Wing stores for additional payload housing.

- Structural hard-points included in wing design.
- Various concepts have been developed.
- Data review and feasibility studies in progress.

High bandwidth telemetry of experimenter data.

- Aircraft is configured for high-gain Ku band antenna.
- Required hardware is available but implementation is not funded.

More aggressive flight operations for science objectives.

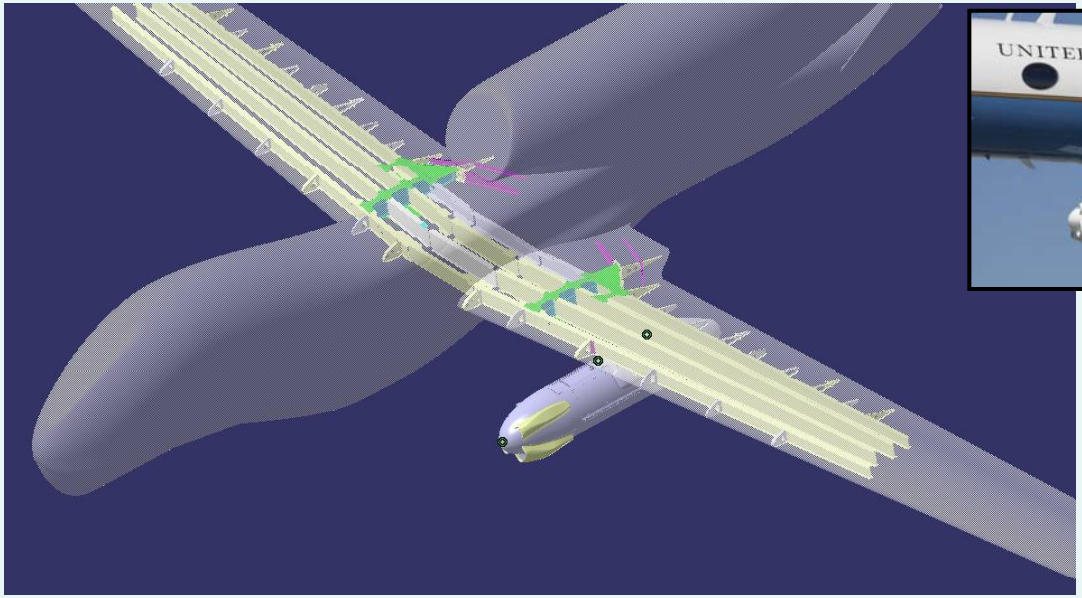
- Vertical profiling to lower altitudes, operations in the vicinity of hazardous weather.
- Dependent on:
  - Airspace policy development for UAS.
  - Operational confidence to be gained from experience.

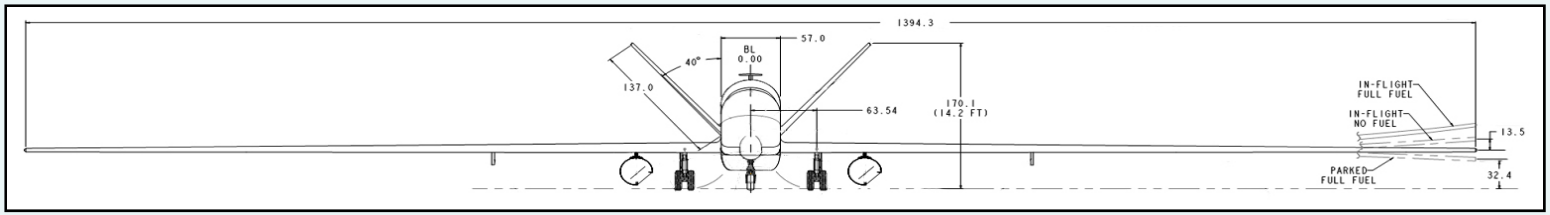
- Global Hawk Overview -

Proposed Future Payloads

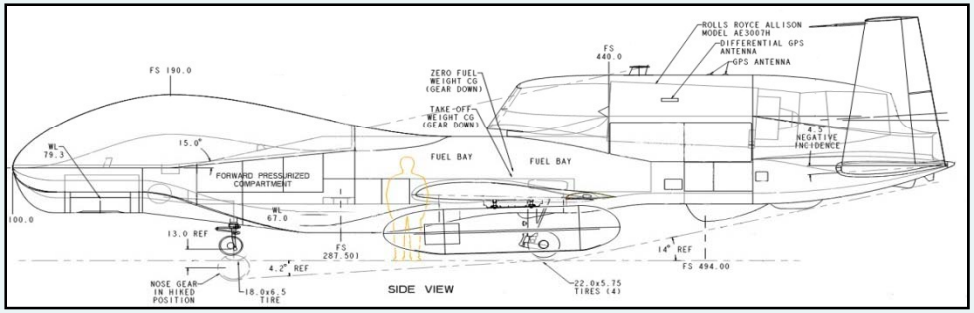
UAV-SAR (JPL)

Two Pods to be used (only one shown)



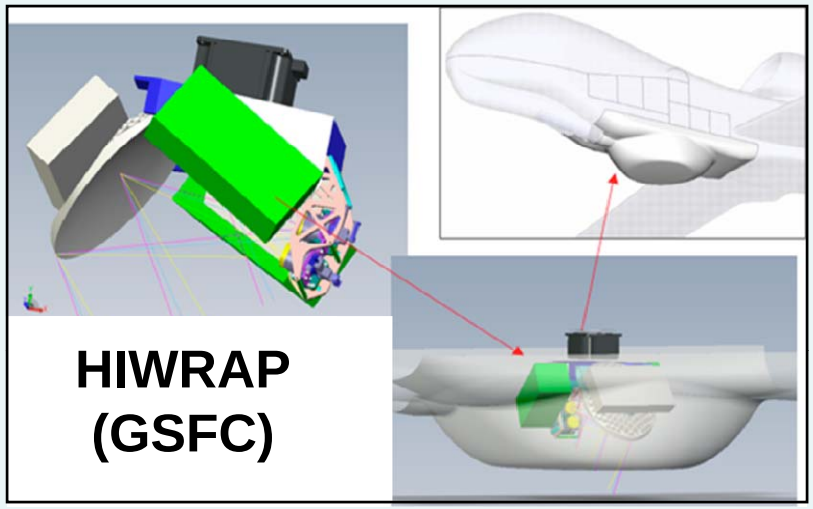


Effort may lead to the development of Generic GH Pods for future Payloads

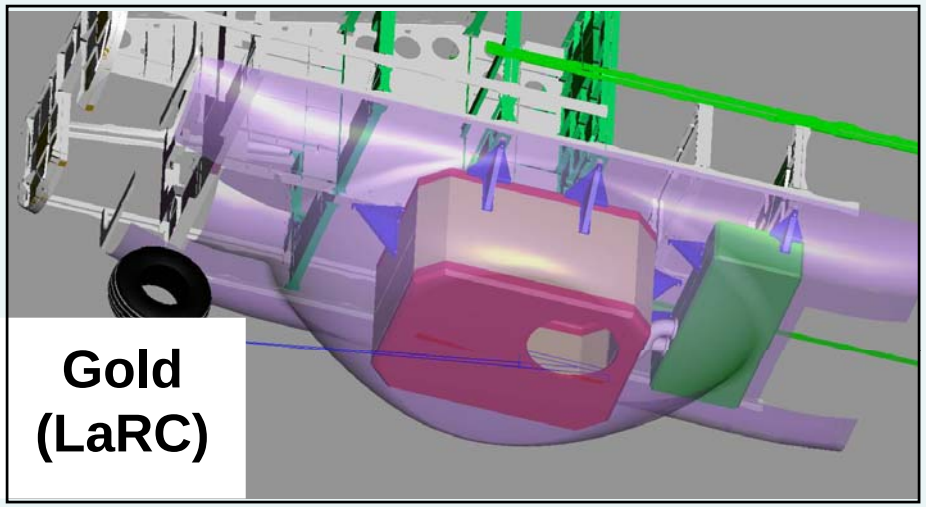


- Global Hawk Overview -

Proposed Future Payloads (cont)



Ku and Ka band radar for the measurement of wind and rain profiles.



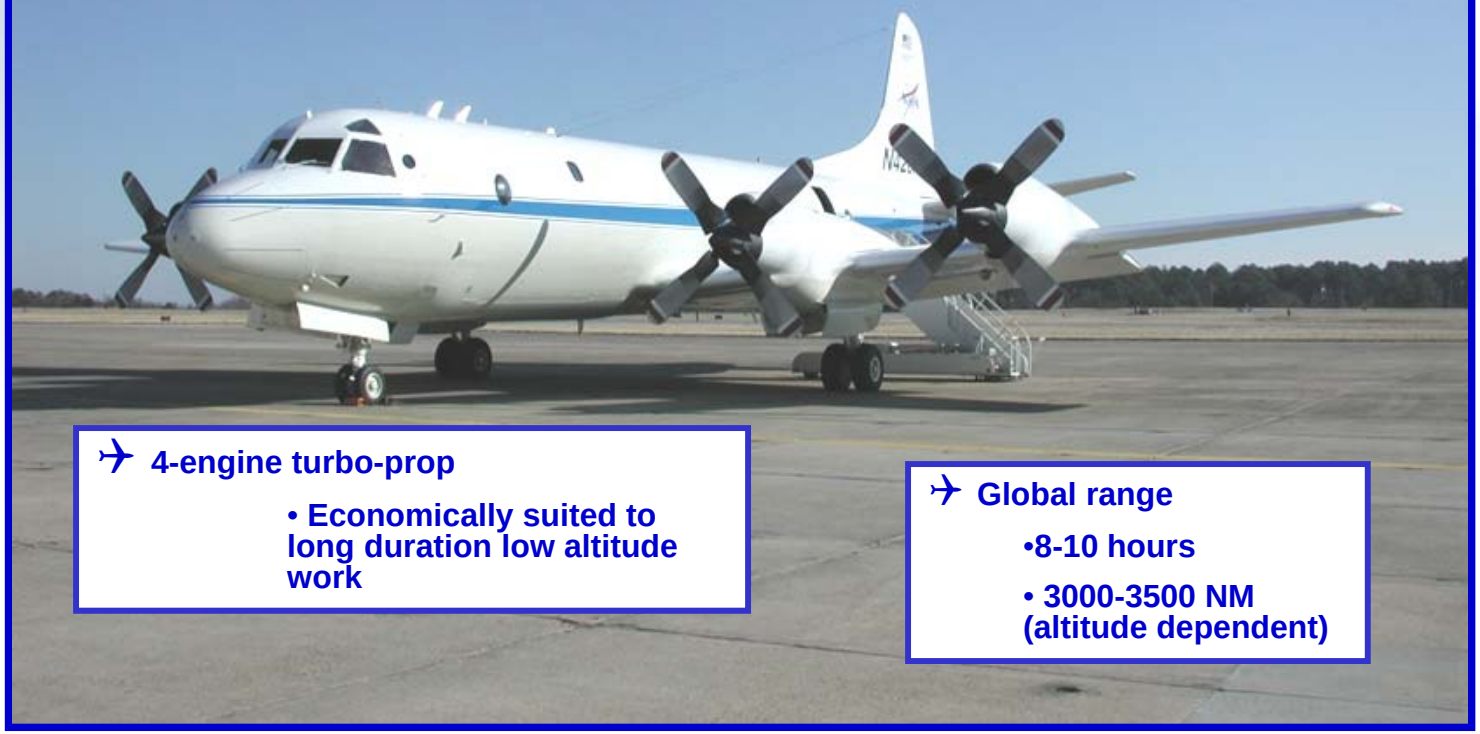
Backscatter LIDAR for accurate measurements of ozone and aerosols in the troposphere.

Both instruments will require a NGC developed "Deep Radome"

P-3B Scientific Accommodations

Goddard Space Flight Center - Wallops Flight Facility - Airborne Science

- "Glass" cockpit & flight management system
  - IRS & GPS-coupled
  - Accommodates in-flight changes to experiment profiles
  - Outputs standard ARINC-429 bus
  - Next upgrade: Dryden Data System



- 4-engine turbo-prop
  - Economically suited to long duration low altitude work

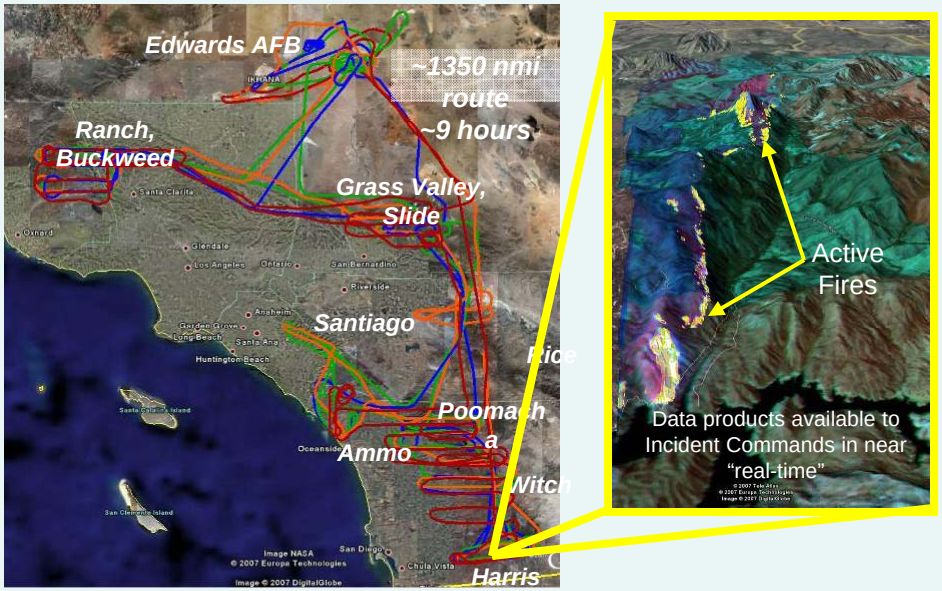
- Global range
  - 8-10 hours
  - 3000-3500 NM (altitude dependent)

NASA WB-57 Johnson Space Center

Ikhana - Western States Fire Mission

Long Range, Duration Flights Over the Western States

Flight operations with the Ikhana have demonstrated unprecedented UAS capability for data collection in the civil air space



Emergency Response Missions into Congested Airspace

Esperanza Fire

Oct 27, 2006: CA OES requests NASA assistance

- 40,000 acres (62 sq mi)
- 5 firefighters killed
- 34 homes destroyed

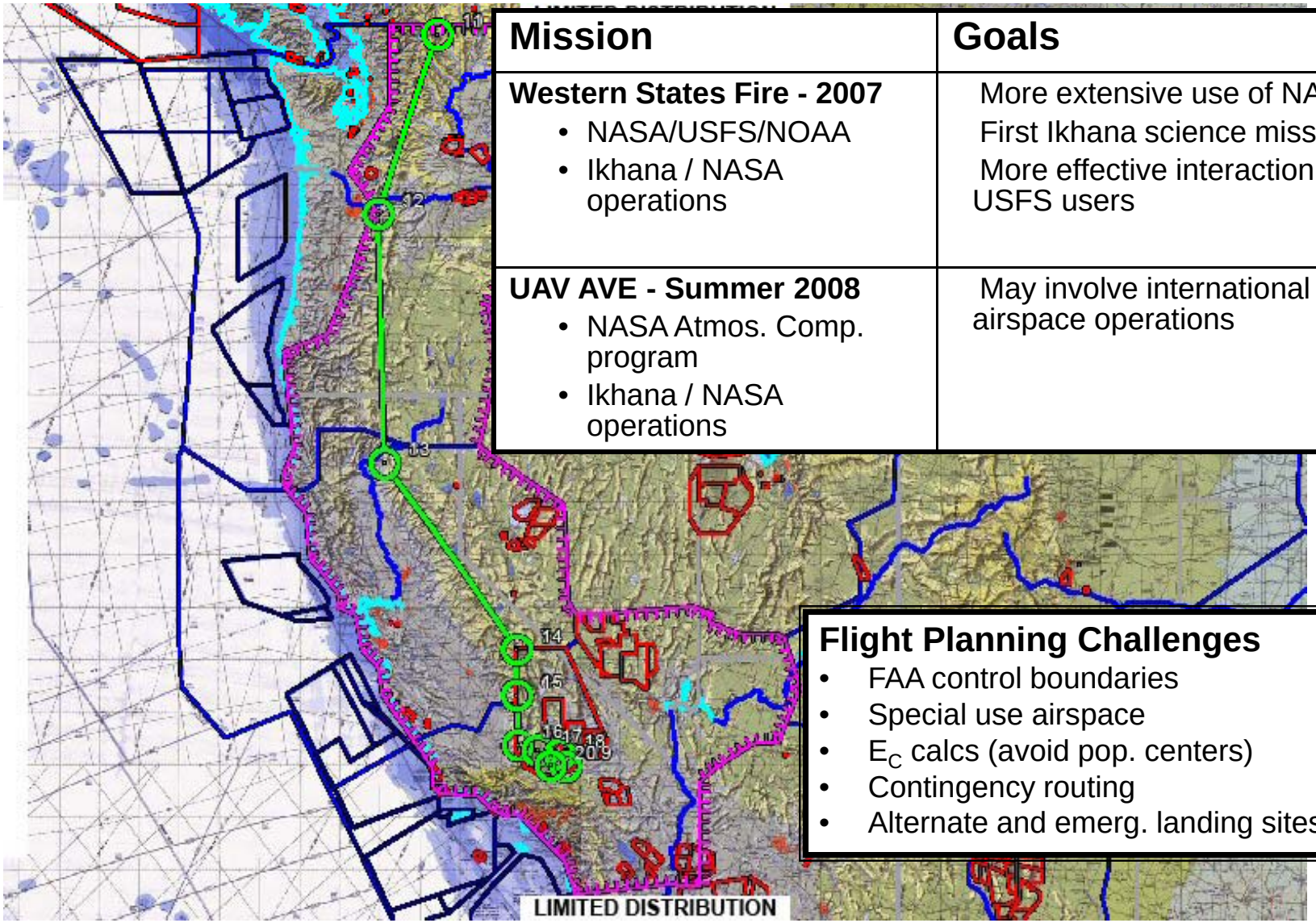
Oct 28, 2006: Altair UAV deployed

- 16:27 flight hours
- 94 images, 44 shapefiles
- Incident Command

"Getting real time UAS data to Incident Command Center was one of two major accomplishments this past year" (Director, CA Dept. Forestry)

"If we had NASA's technology earlier, we could have gotten fires under control sooner." (Director, CA Office of Emergency Service)

Mission Demonstrations - Planned



Mission	Goals
Western States Fire - 2007 • NASA/USFS/NOAA • Ikhana / NASA operations	More extensive use of NAS First Ikhana science mission More effective interaction with USFS users
UAV AVE - Summer 2008 • NASA Atmos. Comp. program • Ikhana / NASA operations	May involve international airspace operations

Flight Planning Challenges

- FAA control boundaries
- Special use airspace
- E_C calcs (avoid pop. centers)
- Contingency routing
- Alternate and emerg. landing sites

Platform Comparison Summary

Platform Name	Center	Duration (Hours)	Payload (lbs.)	Subsidized Cost (SMD)	Max Altitude (ft.)	Airspeed (knots)	Range (Nmi)
Core Aircraft							
ER-2	DFRC	12	2900	$3500	>70000	410	>5000
WB-57	JSC	6	6000	$3500	65000	410	2172
DC-8	DFRC	12	30000	$6500	41000	450	5400
P-3B	WFF	12	16000	$3500	30000	330	3800
Gulfstream III	DFRC	7	2610	$2500	45000	459	3400
UAS							
Ikhana	DFRC	24	>2000	$3500	40000	171	3500
Global Hawk	DFRC	31	1500	$3500	60000	335	11004

Suborbital Commercial Vehicles
(Several Companies in Development – X-Prize Winner shown for illustrative purposes)